TEXAS WATER DEVELOPMENT BOARD

REPORT 142

RECONNAISSANCE OF THE OXYGEN BALANCE AND THE VARIATION OF SELECTED NUTRIENTS IN THE SAN ANTONIO RIVER DURING LOW FLOW

By

Jack Rawson
United States Geological Survey

Prepared by the U.S. Geological Survey
in cooperation with the
Texas Water Development Board

February 1972

TEXAS WATER DEVELOPMENT BOARD

Published and distributed
by the
Texas Water Development Board
Post Office Box 13087
Austin, Texas 78711

TABLE OF CONTENTS

TABLES

FIGURES

TABLE OF CONTENTS (Cont'd.)

RECONNAISSANCE OF THE OXYGEN BALANCE AND THE VARIATION OF SELECTED NUTRIENTS IN THE SAN ANTONIO RIVER DURING LOW FLOW

ABSTRACT

This water-quality reconnaissance of the San Antonio River was made to describe the progress of waste assimilation, to delineate the critical reach of the river (the reach in which the minimum dissolved-oxygen concentration occurs), and to determine the concentrations of selected nutrients in the river during the low-flow period June 16-19, 1969.

Water-quality and discharge data were obtained at seven sites in the 136.5-mile reach of the San Antonio River between Farm Road 1518 near Elmendorf and the San Antonio River at Goliad. The mean discharge in this reach ranged from 128 cfs (cubic feet per second) near Elmendorf to 260 cfs at Goliad. Most of the flow at the site near Elmendorf consisted of treated sewage effluent on the basis of reported discharges. The quantity of treated effluent released into the San Antonio River about 18 miles upstream from the site near Elmendorf ranged from 46 to 138 cfs and averaged about 100 cfs.

The time-weighted concentration of dissolved oxygen and the dissolved-oxygen deficit, during the period from 1200 hours on June 17 to 1400 hours on June 19, show that the critical part of the reach studied extended from site 1 (mile 203.0) to site 2 (mile 175.5). The dissolved-oxygen content of water in this 27.5-mile reach averaged about 5.0 mg/l (milligrams per liter), and the dissolved-oxygen deficit averaged about 3.0 mg/l.

The time-weighted averages of other water-quality parameters or constituents for site 1 near Elmendorf were as follows: BOD (biochemical oxygen demand), 14 mg/l; total nitrogen, 7.6 mg/l; and total phosphate, 9.7 mg/l. At most downstream sites, dilution of waste effluent, supplemented by bacterial stabilization of organic matter and probable algal uptake of nitrogen and phosphorus, resulted in an increase in the dissolved oxygen and decrease in the dissolved-oxygen deficit, BOD, and concentrations of total nitrogen and total phosphate. The time-weighted averages of these water-quality parameters or constituents for the San Antonio River at site 7 at Goliad were as follows: BOD, 1.8 mg/l; dissolved oxygen, 7.2 mg/l; dissolved-oxygen deficit, 0.7 mg/l; total nitrogen, 3.4 mg/l; and total phosphate, 2.5 mg/l.

RECONNAISSANCE OF THE OXYGEN BALANCE AND THE VARIATION OF SELECTED NUTRIENTS IN THE SAN ANTONIO RIVER DURING LOW FLOW

INTRODUCTION

Planning for water-resources development and for water-quality management in Texas requires a knowledge of the nutrient content and the waste-assimilative capacity of the principal streams in the State under varying streamflow conditions. Since January 1968, the U.S. Geological Survey, in cooperation with the Texas Water Development Board, has periodically determined the concentrations of selected nutrients and dissolved oxygen and the BOD of water at a network of sites on most of the principal streams. Results of these periodic measurements through September 1968 at 58 sites have been compiled by Dupuy, Manigold, and Schulze (1970). Four of these sites are on the San Antonio River downstream from metropolitan San Antonio.

To supplement data being collected at the four sites in the periodic water-quality network, the U.S. Geological Survey, in cooperation with the Texas Water Development Board, made this low-flow reconnaissance of the San Antonio River. The purposes of the study were to describe the progress of waste assimilation, to delineate the critical reach (the reach in which the minimum dissolved-oxygen concentration occurs), and to determine the concentrations of selected nutrients in the San Antonio River during low flow.

LOCATION OF REACH STUDIED

The San Antonio River rises in the city of San Antonio near the center of Bexar County, joins the Medina River about 15 miles south of the city, and flows southeastward for more than 200 river miles to its junction with the Guadalupe River (Figure 1). Cibolo Creek, the principal tributary downstream from the Medina River, joins the San Antonio River at mile 131.0. (In this report, river mileages for the mainstem are measured upstream from the confluence of the San Antonio and Guadalupe Rivers, which is designated as mile 0.0. Mileage for Cibolo Creek is that at its mouth.)

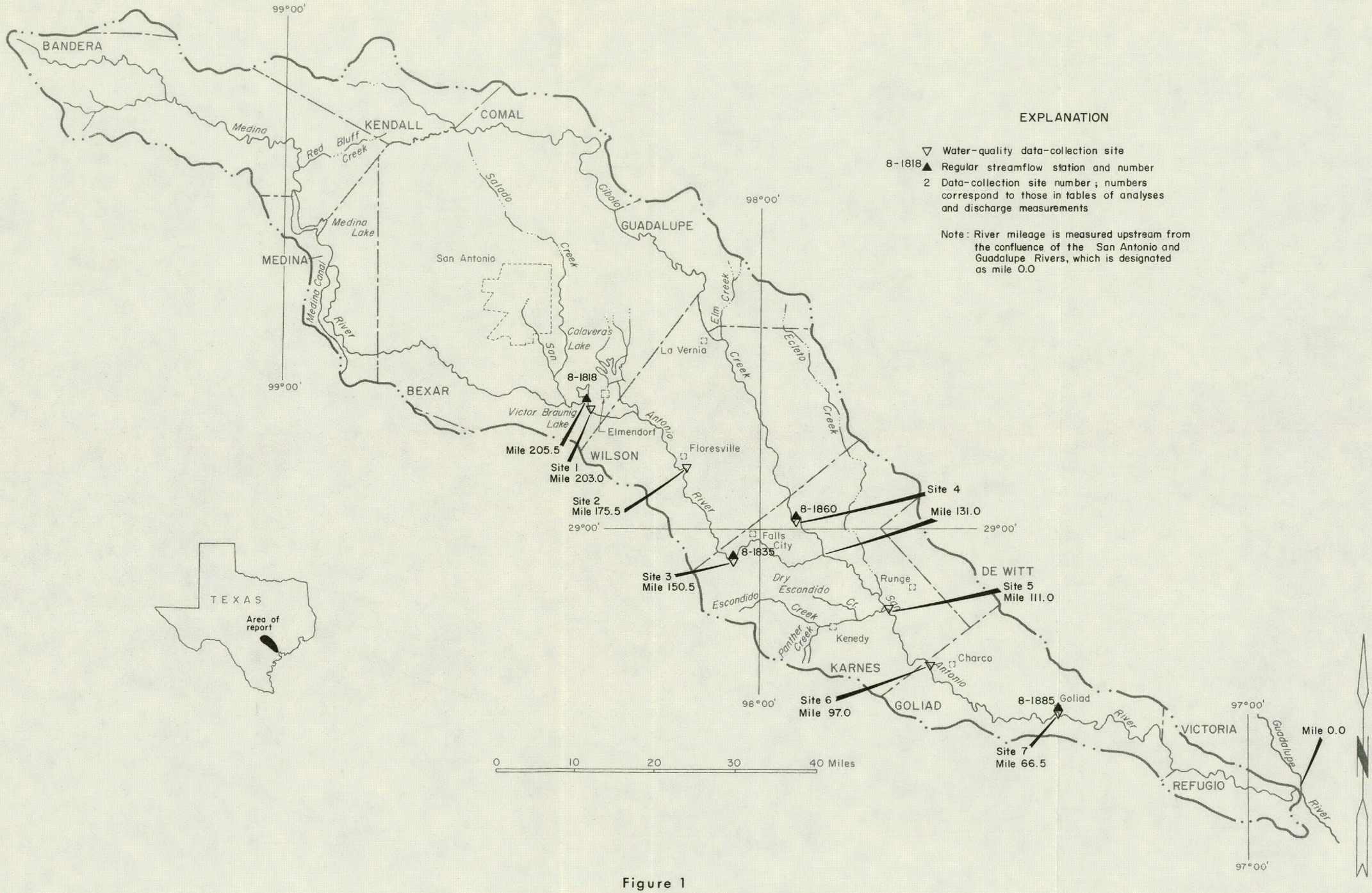
The 136.5-mile reach of the San Antonio River included in this study extends from Farm Road 1518 near Elmendorf (site 1, mile 203.0) to the Geological Survey's streamflow and daily chemical-quality station at Goliad (site 7, mile 66.5).

ENVIRONMENTAL CONDITIONS

Because most of the critical conditions related to decomposition of organic material in a stream occur when temperature is high and streamflow is low, this reconnaissance was made during a summer low-flow period, June 16-19, 1969.

During the investigation, water temperature throughout the reach studied averaged about 28°C. Weather records for Floresville and Goliad indicate that the investigation was preceded by 10 days of no rainfall. Records for the Geological Survey's streamflow stations San Antonio River near Elmendorf (mile 205.5), San Antonio River near Falls City (site 3, mile 150.5), and San Antonio River at Goliad (site 7, mile 66.5) showed typical patterns of seasonal recession for at least a week prior to the study (Figure 2). During the period June 16-19, water discharge at the Goliad station averaged 260 cfs, as compared with the long-term average (1924-28, 1939-68) of 554 cfs.

Low flow of the San Antonio River downstream from metropolitan San Antonio is sustained partly by treated domestic and some industrial wastes. According to records furnished by the city of San Antonio through the Alamo Area Council of Governments, the combined discharges from 19 sewage treatment plants to the San Antonio River and its tributaries, upstream from Elmendorf, average about 153 cfs. Discharge from the city of San Antonio's Rilling Road Sewage Treatment Plant, which is located about 18 miles upstream from the reach studied, account for about 87 percent (average of 133 cfs) of the combined releases. During this



EXPLANATION

▽ Water-quality data-collection site

8-1818▲ Regular streamflow station and number

2 Data-collection site number; numbers correspond to those in tables of analyses and discharge measurements

Note: River mileage is measured upstream from the confluence of the San Antonio and Guadalupe Rivers, which is designated as mile 0.0

Figure 1
Locations of Data-Collection Sites

Base from Geological Survey, 1954

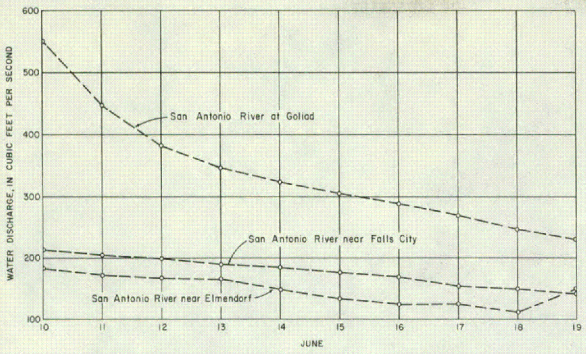


Figure 2.—Hydrographs of Flow Recession for Selected Sites on the San Antonio River

investigation, discharge from the Rilling Road plant into the San Antonio River ranged from about 46 to 138 cfs and averaged about 100 cfs. The diurnal variations of discharge from the plant are shown on Figure 3.

SIGNIFICANCE OF WATER-QUALITY DATA

All living organisms require oxygen in one form or another to maintain the metabolic processes that produce energy for growth and reproduction. Consequently, one of the more important aspects of waste assimilation is the stream's ability to maintain an adequate dissolved-oxygen concentration.

The solubility of oxygen in water is influenced by several factors, among which are atmospheric pressure, temperature, and substances dissolved in the water. A stream in which no oxygen is being utilized for chemical or biological oxidation usually will be nearly saturated with oxygen. However, if the quantity of organic bacterial food is increased, the utilization of oxygen by bacteria may exceed the adsorption of oxygen from the atmosphere and oxygen production by algae and result in a dissolved-oxygen deficit (difference at water temperature between saturated concentration and actual concentration at the same temperature). If organic material is present in excessive amounts, complete depletion of oxygen may result and anaerobic or septic conditions may develop. As the organic food is depleted, bacterial activity and the demand for oxygen are reduced. Eventually, the rate at which oxygen is replenished will exceed the rate of consumption, and the amount of dissolved oxygen will gradually increase.

Factors that affect reaeration or reoxygenation include the dissolved-oxygen deficit and the depth, volume, velocity, and turbulence of flow. Also, during daylight hours, photosynthesis by algae may contribute oxygen to a stream.

The major factor responsible for oxygen consumption in a stream is the bacterial stabilization of organic matter. Consequently, the rate of oxygen consumption is governed partly by the nature and concentration of organic matter in the water. Although several methods have been developed to measure the oxygen demand of organic matter in water, the most widely used method is the BOD (5-day, 20°C biochemical oxygen demand) determination, which measures the quantity of oxygen utilized by bacteria during the stabilization of readily decomposable organic matter and oxidizable inorganic matter.

Streams receiving domestic wastes may contain large quantities of nitrogen and phosphorus. If the concentrations of nitrogen, phosphorus, and organic matter are excessive, massive algal blooms may produce a variety of nuisance conditions. Although photosynthesis by algae may contribute large quantities of oxygen to a stream during daylight hours, the dissolved oxygen may be reduced drastically by algal respiration during the night after photosynthesis ceases.

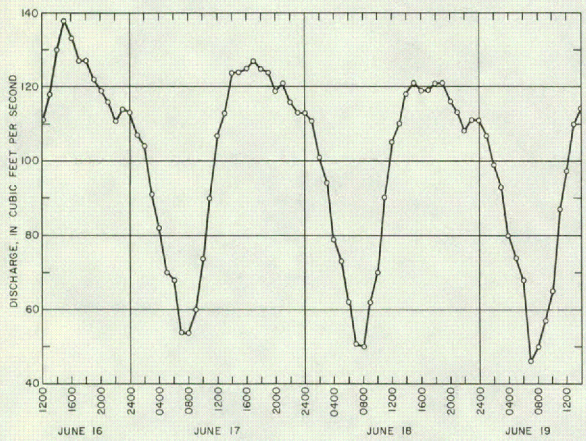


Figure 3.—Diurnal Variations of Discharge of Effluent from the San Antonio Rilling Road Sewage Treatment Plant

METHODS OF STUDY

Water-Quality Sampling Program

Water-quality data were collected at six sites on the mainstem San Antonio River downstream from its confluence with the Medina River (Figure 1). Because of limited funds and field equipment available for this study, data were not collected simultaneously at all sites. Instead, field crews assigned to adjacent sites in a subreach alternated between the sites at about 3- to 4-hour intervals.

Cibolo Creek, the principal tributary in the reach studied, was sampled once near the beginning of the study and once near the end.

Dissolved oxygen and pH were determined in the field. Samples for the determination of nitrogen and phosphorus were treated with chloroform and were refrigerated until analysis was begun. Samples for the determination of BOD were refrigerated at a temperature of about 1°C, and analysis was begun within four days. The results of these and other water-quality determinations are shown in Table 1.

Determination of Water Discharge

During this reconnaissance, continuous records of discharge were collected at four Geological Survey streamflow stations in or proximate to the reach studied (Figure 1). Three of these stations are on the San Antonio River. These stations, in downstream order, are San Antonio River near Elmendorf, 2.5 miles upstream from the initial site in the reach studied; San Antonio River near Falls City; and San Antonio River at Goliad. The fourth station is on Cibolo Creek. To supplement streamflow records for these stations, discharge was measured once at each of the sites where water-quality data were collected. The results of these measurements are shown in Table 2.

ANALYSIS OF DATA

Streamflow Records

Figure 4 is a profile of mean water discharge of the San Antonio River (miles 203.0 to 66.5) for the period June 16-19, 1969. This profile, which was prepared from records for Geological Survey streamflow stations, was used to estimate the mean water discharge at ungaged sites where water-quality data were collected. Discharge data for the gaging stations and ungaged data-collection sites in the reach studied are shown in Table 2. The discharge estimates for most ungaged sites correlate well with results obtained at those sites during single discharge measurements.

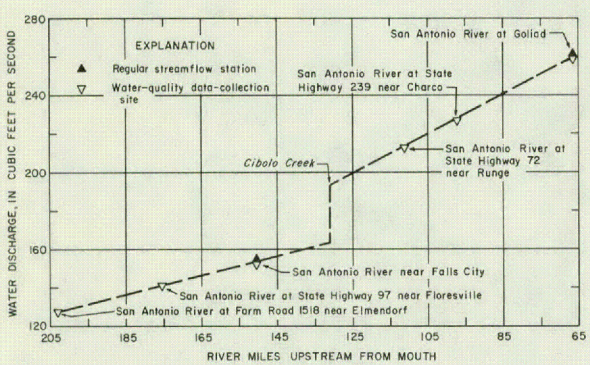


Figure 4.—Mean Water Discharge for the San Antonio River, June 16-19, 1969

Waste assimilation and decrease in the concentrations of nutrients in a stream are effected partly by dilution of wastes by surface-water and ground-water inflow. During this study, waste effluent from the Rilling Road Sewage Treatment Plant averaged about 100 cfs. Data in Table 2 and Figure 4 indicate that the mean discharge of the San Antonio River ranged from 128 cfs at site 1 near Elmendorf to 260 cfs at site 7 at Goliad. Inflow from Cibolo Creek at mile 131.0 averaged about 30 cfs. Thus, the average quantity of flow available for dilution in the reach increased from about 28 cfs at site 1 to 160 cfs at site 7.

Water-Quality Records

Dissolved Oxygen and Biochemical Oxygen Demand

Water-quality data for six sites on the San Antonio River and one site on Cibolo Creek are shown in Table 1. The diurnal variations of dissolved oxygen and BOD for the San Antonio River at Farm Road 1518 near Elmendorf are shown graphically in Figure 5. These data show that the dissolved-oxygen content and BOD of flow that passed site 1 near Elmendorf during the period June 16-19 ranged from 4.4 to 5.6 mg/l and from 9.0 to 20 mg/l, respectively. Flow at this site, which averaged 128 cfs, consisted mostly of treated sewage effluent on

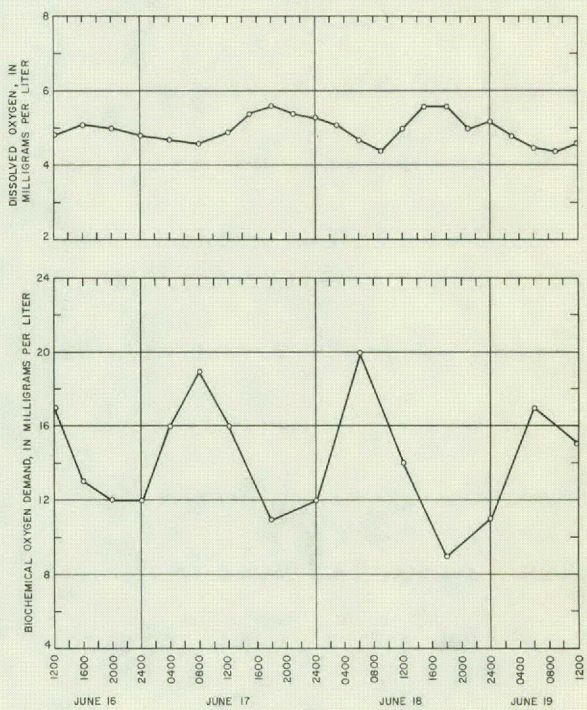


Figure 5.—Diurnal Variations of Dissolved Oxygen and Biochemical Oxygen Demand, San Antonio River at Farm Road 1518 near Elmendorf

Table 1.--Results of water-quality analyses for streams in the San Antonio River basin, Texas, June 16-19, 1969

(Results in milligrams per liter except as indicated)

Date (1969)	Time	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Phosphate (PO_4)		Dissolved solids (calculated)	Hardness as $CaCO_3$	Specific conductance (micromhos at 25° C)	pH	Dissolved oxygen (DO)		Biochemical oxygen demand (BOD)	Temperature (°C)	Ammonia nitrogen (N)	Nitrite nitrogen (N)	Nitrate nitrogen (N)	Organic nitrogen (N)
										Ortho	Total		Calcium magnesium			mg/l	Percent saturation						
SITE 1. SAN ANTONIO RIVER AT FARM ROAD 1518 NEAR ELMENDORF (MILE 203.0)																							
June 16....	1200	--	--	--	--	--	--	--	--	5.8	5.9	--	--	958	7.6	4.8	59	17	27.0	3.6	0.94	2.8	1.3
	1600	--	--	--	--	--	--	--	--	4.6	4.7	--	--	950	7.7	5.1	65	13	29.0	2.3	1.1	3.0	.78
	2000	--	--	--	--	--	--	--	--	3.6	3.7	--	--	938	7.5	5.0	65	12	29.5	2.0	1.1	2.2	.66
	2400	--	--	--	--	--	--	--	--	1.6	2.2	--	--	934	7.5	4.8	60	12	27.5	.97	3.1	1.6	.70
June 17....	0400	--	--	--	--	--	--	--	--	1.8	2.1	--	--	921	7.6	4.7	58	16	27.0	1.9	3.0	1.1	1.5
	0800	--	--	--	--	--	--	--	--	2.5	2.9	--	--	918	7.5	4.6	56	19	26.5	3.3	1.2	3.0	.80
	1200	--	--	--	--	--	--	--	--	2.5	2.6	--	--	902	7.6	4.9	61	16	27.5	2.8	1.2	3.4	1.0
	1500	17	92	20	64	5.1	282	91	80	2.4	2.4	536	312	883	7.7	5.4	69	--	28.5	2.1	1.2	4.2	1.0
	1800	--	--	--	--	--	--	--	--	2.0	2.2	--	--	896	7.5	5.6	72	11	29.0	2.0	1.4	3.9	.62
	2100	--	--	--	--	--	--	--	--	2.2	2.4	--	--	902	7.5	5.4	68	--	28.0	1.7	1.3	4.0	.54
	2400	--	--	--	--	--	--	--	--	3.2	3.3	--	--	922	7.5	5.3	66	12	27.5	1.4	1.2	4.7	1.0
June 18....	0300	--	--	--	--	--	--	--	--	8.9	9.2	--	--	963	7.6	5.1	64	--	27.5	2.7	1.3	4.0	1.2
	0600	19	92	21	81	7.4	259	94	102	17	17	583	316	996	7.5	4.7	58	20	27.0	4.4	1.1	2.9	1.3
	0900	--	--	--	--	--	--	--	--	18	19	--	--	975	7.6	4.4	54	--	27.0	3.9	2.8	.7	1.3
	1200	--	--	--	--	--	--	--	--	15	16	--	--	974	7.6	5.0	62	14	27.5	3.4	1.2	2.9	.98
	1500	--	--	--	--	--	--	--	--	11	11	--	--	948	7.7	5.6	72	--	29.0	2.4	1.2	3.0	1.3
	1800	--	--	--	--	--	--	--	--	7.9	7.9	--	--	950	7.6	5.6	73	9.0	29.5	2.0	1.2	3.2	1.3
	2100	--	--	--	--	--	--	--	--	5.6	5.6	--	--	951	7.5	5.0	64	--	29.0	1.7	1.2	3.8	.82
	2400	--	--	--	--	--	--	--	--	5.5	5.5	--	--	951	7.5	5.2	67	11	28.5	1.5	1.1	3.8	.75
June 19....	0300	--	--	--	--	--	--	--	--	11	11	--	--	967	7.5	4.8	61	--	28.0	1.6	.17	.1	1.0
	0600	--	--	--	--	--	--	--	--	16	17	--	--	987	7.5	4.5	56	17	27.5	2.4	.35	.4	1.3
	0900	--	--	--	--	--	--	--	--	18	18	--	--	971	7.5	4.4	55	--	27.5	4.0	1.1	3.0	1.8
	1200	--	--	--	--	--	--	--	--	14	15	--	--	963	7.6	4.6	58	15	28.0	2.4	.49	1.8	1.7
SITE 2. SAN ANTONIO RIVER AT STATE HIGHWAY 97 NEAR FLORESVILLE (MILE 175.5)																							
June 16....	1400	--	--	--	--	--	--	--	--	11	11	--	--	960	7.6	4.0	51	11	28.0	1.5	0.57	3.8	0.06
	1800	--	--	--	--	--	--	--	--	7.6	7.8	--	--	975	7.5	4.9	63	5.7	29.0	.81	.55	4.1	.62
	2200	--	--	--	--	--	--	--	--	5.7	5.8	--	--	975	7.5	4.7	59	4.0	27.5	.23	.58	4.8	.53
June 17....	0200	--	--	--	--	--	--	--	--	6.3	6.3	--	--	987	7.6	4.4	54	4.2	27.0	.47	.55	4.5	.50
	0600	--	--	--	--	--	--	--	--	9.2	9.4	--	--	992	7.5	3.7	46	6.5	27.0	.95	.61	4.2	.34
	1000	19	98	21	81	7.3	285	106	100	12	12	606	331	1020	7.6	3.6	44	12	27.0	1.7	.64	3.8	.70
	1330	--	--	--	--	--	--	--	--	10	11	--	--	996	7.6	4.8	61	11	28.0	.92	1.4	1.3	.62
	1630	--	--	--	--	--	--	--	--	9.5	9.5	--	--	996	7.5	5.1	65	--	28.5	1.2	.50	3.6	.52
	1930	--	--	--	--	--	--	--	--	7.5	7.5	--	--	987	7.4	5.2	67	5.4	28.5	.43	.60	3.7	.70
	2230	--	--	--	--	--	--	--	--	6.0	6.3	--	--	975	7.4	5.2	65	--	27.5	.29	.70	4.0	.98
June 18....	0130	--	--	--	--	--	--	--	--	4.7	4.8	--	--	983	7.5	4.8	60	3.2	27.5	.02	2.5	1.5	.87
	0430	--	--	--	--	--	--	--	--	4.0	4.1	--	--	979	7.6	4.8	59	--	26.5	.00	.16	.0	.80
	0730	--	--	--	--	--	--	--	--	4.0	4.1	--	--	976	7.6	4.4	54	--	26.5	.02	.10	.6	.99
	1030	--	--	--	--	--	--	--	--	4.9	5.4	--	--	992	7.7	4.1	51	--	27.0	.54	.85	4.3	.78
	1330	--	--	--	--	--	--	--	--	5.2	5.5	--	--	1000	7.6	4.8	61	6.7	28.0	.86	.70	4.1	.72
	1630	--	--	--	--	--	--	--	--	4.7	5.1	--	--	996	7.7	5.4	69	--	28.5	.27	.41	4.6	1.1
	1930	--	--	--	--	--	--	--	--	4.1	4.5	--	--	987	7.6	5.8	74	4.2	28.5	.25	.64	4.1	.92
	2230	--	--	--	--	--	--	--	--	3.3	3.7	--	--	976	7.4	5.4	68	--	27.5	.34	.21	.2	.76
June 19....	0130	--	--	--	--	--	--	--	--	3.1	3.1	--	--	983	7.6	5.4	68	2.9	27.5	.41	.47	1.2	.91
	0430	--	--	--	--	--	--	--	--	2.4	2.9	--	--	975	7.6	5.4	68	--	27.5	.45	.19	.3	.71
	0730	--	--	--	--	--	--	--	--	2.0	2.1	--	--	957	7.5	5.0	62	3.0	27.0	.36	.07	.5	.64
	1030	--	--	--	--	--	--	--	--	2.5	2.5	--	--	952	7.6	4.8	60	--	27.5	.38	.47	4.6	.25
	1330	18	98	20	71	5.7	294	104	88	2.3	2.4	574	327	950	7.5	5.0	64	4.5	28.5	.27	.46	4.4	.46

Table 1.--Results of water-quality analyses for streams in the San Antonio River basin, Texas, June 16-19, 1969--continued

(Results in milligrams per liter except as indicated)

Date (1969)	Time	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Phosphate (PO_4) Ortho	Phosphate (PO_4) Total	Dissolved solids (calculated)	Hardness as $CaCO_3$ Calcium magnesium	Specific conductance (micromhos at 25° C)	pH	Dissolved oxygen (DO) mg/l	Dissolved oxygen (DO) Percent saturation	Biochemical oxygen demand (BOD)	Temperature (°C)	Ammonia nitrogen (N)	Nitrite nitrogen (N)	Nitrate nitrogen (N)	Organic nitrogen (N)
SITE 3. SAN ANTONIO RIVER NEAR FALLS CITY (MILE 150.5)																							
June 17...	1200	19	105	23	95	6.7	303	129	118	7.6	7.6	670	356	1100	7.8	5.4	68	2.4	28.0	0.36	0.21	3.9	0.53
	1500	--	--	--	--	--	--	--	--	5.9	6.3	--	--	1100	7.7	5.4	69	--	28.5	.45	.17	2.1	.71
	1800	--	--	--	--	--	--	--	--	4.7	5.8	--	--	1110	7.6	5.6	72	2.7	28.5	.47	.01	1.2	.78
	2100	--	--	--	--	--	--	--	--	4.2	5.3	--	--	1110	7.5	5.3	66	--	27.5	.68	.07	.2	.77
	2400	--	--	--	--	--	--	--	--	4.8	5.4	--	--	1130	7.7	6.0	74	2.1	27.0	.41	.02	.5	.85
June 18...	0300	--	--	--	--	--	--	--	--	6.3	6.9	--	--	1140	7.6	5.5	68	--	27.0	.56	.44	1.9	1.0
	0600	--	--	--	--	--	--	--	--	8.2	8.4	--	--	1150	7.5	4.9	60	4.5	26.0	.23	.03	.2	.71
	0900	--	--	--	--	--	--	--	--	9.0	9.2	--	--	1150	7.6	4.5	56	--	27.0	.95	.32	4.0	1.1
	1200	--	--	--	--	--	--	--	--	10	10	--	--	1150	7.4	5.2	67	4.7	28.5	.29	.19	.7	1.4
	1500	--	--	--	--	--	--	--	--	9.6	9.6	--	--	1130	7.8	5.6	72	--	29.0	.41	.32	4.2	.40
	1800	--	--	--	--	--	--	--	--	8.0	8.0	--	--	1130	7.7	5.8	73	2.7	28.0	.18	.17	4.5	.56
	2100	--	--	--	--	--	--	--	--	6.0	6.4	--	--	1140	7.6	6.6	82	--	27.5	.32	.07	.9	.94
	2400	--	--	--	--	--	--	--	--	4.8	5.2	--	--	1150	7.6	6.8	85	1.9	27.5	.47	.03	.8	.70
June 19...	0300	--	--	--	--	--	--	--	--	4.8	5.0	--	--	1140	7.8	7.0	86	--	27.0	.41	.04	.6	.75
	0600	18	114	25	100	6.7	317	144	126	6.9	6.9	718	392	1160	7.6	6.2	76	2.6	26.5	.00	.14	4.8	.55
	0900	--	--	--	--	--	--	--	--	8.2	8.5	--	--	1170	7.6	5.4	66	--	26.5	.28	.10	3.8	.94
	1200	--	--	--	--	--	--	--	--	9.0	9.4	--	--	1150	7.7	5.5	70	3.9	28.0	.28	.72	1.7	1.2
SITE 4. CIBOLO CREEK NEAR FALLS CITY (MILE 131.0)																							
June 17...	1100									0.03	0.14			1290	8.2	7.9	99	1.6	27.5	0.14	0.01	1.7	0.21
June 19...	1430	15	120	22	132	7.1	246	242	169	.02	.18	833	390	1330	8.1	11.6	149	1.7	29.0	.18	.00	.9	.22
SITE 5. SAN ANTONIO RIVER AT STATE HIGHWAY 72 NEAR RUNGE (MILE 111.0)																							
June 17...	1330	21	117	23	108	7.7	311	150	144	7.8	7.8	751	386	1210	7.6	7.6	97	2.2	28.5	0.12	0.05	4.2	0.51
	1630	--	--	--	--	--	--	--	--	6.7	6.8	--	--	1210	7.7	7.6	99	--	29.5	.14	.50	.9	.93
	1930	--	--	--	--	--	--	--	--	5.6	7.3	--	--	1210	8.0	7.8	100	2.3	29.0	.20	.02	.2	.71
	2230	--	--	--	--	--	--	--	--	4.6	4.9	--	--	1220	7.8	7.4	94	--	28.0	.27	.04	.4	1.1
June 18...	0130	--	--	--	--	--	--	--	--	4.2	4.5	--	--	1230	7.8	7.4	92	2.0	27.5	.41	.01	.4	.87
	0430	--	--	--	--	--	--	--	--	5.1	5.2	--	--	1250	7.9	6.8	84	--	27.0	.27	.20	1.9	.84
	0730	--	--	--	--	--	--	--	--	6.0	6.3	--	--	1250	7.9	6.7	82	2.1	26.5	.36	.02	.4	.66
	1030	--	--	--	--	--	--	--	--	8.0	8.0	--	--	1260	7.9	6.7	84	--	27.5	.32	.18	3.2	.71
	1330	--	--	--	--	--	--	--	--	8.8	8.9	--	--	1270	7.7	7.4	95	2.7	28.5	.23	.08	3.7	.58
	1630	--	--	--	--	--	--	--	--	9.0	9.0	--	--	1260	8.0	8.2	105	--	29.0	.29	.07	3.7	.41
	1930	--	--	--	--	--	--	--	--	8.2	8.2	--	--	1250	8.0	8.0	101	2.7	28.0	.29	.09	2.3	.92
	2230	--	--	--	--	--	--	--	--	6.1	6.8	--	--	1260	7.3	7.4	92	--	27.5	.43	.03	.3	.87
June 19...	0130	--	--	--	--	--	--	--	--	5.5	6.0	--	--	1260	8.0	6.9	86	1.9	27.5	.27	.02	.3	.49
	0430	--	--	--	--	--	--	--	--	5.1	5.1	--	--	1280	7.8	6.8	84	--	27.0	.16	.02	3.3	.46
	0730	--	--	--	--	--	--	--	--	4.1	4.6	--	--	1280	7.9	6.7	83	1.8	27.0	.29	.06	.6	.77
	1030	--	--	--	--	--	--	--	--	4.3	4.8	--	--	1290	7.9	6.7	84	--	27.5	.23	.38	3.5	.85
	1330	21	124	24	120	7.6	326	164	160	5.6	5.8	793	408	1300	7.9	7.4	95	2.5	29.0	.16	.03	1.5	.88
SITE 6. SAN ANTONIO RIVER AT STATE HIGHWAY 239 NEAR CHARCO (MILE 97.0)																							
June 17...	1200	20	119	22	103	6.9	323	142	141	1.4	1.8	723	388	1160	7.6	7.1	91	1.7	28.5	0.38	1.2	0.9	1.1
	1500	--	--	--	--	--	--	--	--	1.8	2.1	--	--	1200	7.9	8.4	112	--	31.0	.20	.22	1.3	1.0
	1800	--	--	--	--	--	--	--	--	2.9	3.0	--	--	1210	7.8	9.0	117	3.2	29.5	.18	.02	3.6	.72
	2100	--	--	--	--	--	--	--	--	4.2	4.4	--	--	1230	7.8	8.4	108	--	28.5	.28	.02	3.9	.95
	2350	--	--	--	--	--	--	--	--	5.2	5.4	--	--	1260	7.8	7.4	92	2.6	27.5	.29	.03	.9	.94
June 18...	0300	--	--	--	--	--	--	--	--	6.3	6.8	--	--	1250	7.8	7.1	88	--	27.0	.09	.98	1.6	1.0
	0600	--	--	--	--	--	--	--	--	7.4	7.6	--	--	1250	7.8	6.9	84	2.0	26.5	.05	.04	3.3	1.1
	0910	--	--	--	--	--	--	--	--	6.5	7.0	--	--	1240	7.8	6.9	85	--	27.0	.32	.41	.9	1.0
	1200	--	--	--	--	--	--	--	--	5.8	6.2	--	--	1240	8.0	7.5	95	2.1	28.0	.23	.03	.4	.86
	1500	--	--	--	--	--	--	--	--	5.6	5.6	--	--	1240	7.9	8.4	108	--	29.0	.07	.01	3.1	.84
	1800	--	--	--	--	--	--	--	--	4.7	4.9	--	--	1260	7.9	8.8	114	2.9	29.5	.09	.01	3.3	.86
	2100	--	--	--	--	--	--	--	--	4.5	4.6	--	--	1270	8.0	8.0	103	--	28.5	.11	.01	3.7	.94
	2400	--	--	--	--	--	--	--	--	4.4	4.8	--	--	1280	7.8	7.3	91	2.2	27.5	.14	.08	.6	.78

(Continued)

Table 1.--Results of water-quality analyses for streams in the San Antonio River basin, Texas, June 16-19, 1969--continued

(Results in milligrams per liter except as indicated)

Date (1969)	Time	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Phosphate (PO_4) Ortho	Phosphate (PO_4) Total	Dissolved solids (calculated)	Hardness as $CaCO_3$ Calcium magnesium	Specific conductance (micromhos at 25° C)	pH	Dissolved oxygen (DO) mg/l	Dissolved oxygen (DO) Percent saturation	Biochemical oxygen demand (BOD)	Temperature (°C)	Ammonia nitrogen (N)	Nitrite nitrogen (N)	Nitrate nitrogen (N)	Organic nitrogen (N)
SITE 6. SAN ANTONIO RIVER AT STATE HIGHWAY 239 NEAR CHARCO (MILE 97.0)--continued																							
June 19...	0300	--	--	--	--	--	--	--	--	5.4	5.6	--	--	1290	7.9	7.2	89	--	27.0	0.23	0.53	1.1	1.0
	0600	--	--	--	--	--	--	--	--	6.0	7.2	--	--	1300	7.9	7.0	86	1.9	27.0	.25	.11	2.2	1.1
	0900	--	--	--	--	--	--	--	--	8.2	8.6	--	--	1300	8.1	7.0	88	--	27.5	.20	.04	3.3	1.3
	1200	23	123	24	119	7.9	322	153	164	8.3	8.3	795	406	1290	8.2	7.9	101	2.6	28.5	.14	.05	3.1	.73
SITE 7. SAN ANTONIO RIVER AT GOLIAD (MILE 66.5)																							
June 17...	1330	22	120	21	102	7.3	329	134	140	1.9	2.6	722	386	1180	7.9	7.2	91	1.7	28.0	0.11	0.02	2.6	1.0
	1630	--	--	--	--	--	--	--	--	1.7	2.4	--	--	1180	7.9	7.6	97	--	28.5	.11	.02	2.8	.83
	1930	--	--	--	--	--	--	--	--	2.3	2.3	--	--	1190	7.9	7.6	97	1.8	28.5	.16	.02	2.7	.93
	2230	--	--	--	--	--	--	--	--	1.4	2.0	--	--	1200	7.8	7.2	91	--	28.0	.20	.18	.9	.93
June 18...	0130	--	--	--	--	--	--	--	--	1.8	2.1	--	--	1200	7.7	6.9	88	1.5	28.5	.20	.02	2.8	.98
	0430	--	--	--	--	--	--	--	--	2.0	2.0	--	--	1210	7.8	6.9	86	--	27.5	.18	.02	3.0	.71
	0730	--	--	--	--	--	--	--	--	1.1	1.9	--	--	1210	7.9	6.7	82	1.2	26.5	.25	.12	1.7	.82
	1030	--	--	--	--	--	--	--	--	1.5	1.8	--	--	1210	7.9	6.9	85	--	27.0	.29	.09	1.9	1.1
	1330	--	--	--	--	--	--	--	--	1.2	1.6	--	--	1200	7.9	7.4	95	1.5	28.5	.56	.03	.2	.91
	1630	--	--	--	--	--	--	--	--	2.0	2.0	--	--	1210	7.9	8.0	103	--	29.0	.20	.02	3.0	.97
	1930	--	--	--	--	--	--	--	--	2.0	2.0	--	--	1200	7.8	7.9	101	1.8	29.0	.11	.02	3.1	1.0
	2230	--	--	--	--	--	--	--	--	1.8	2.0	--	--	1210	7.9	7.3	94	--	28.5	.18	.02	2.2	1.5
June 19...	0130	--	--	--	--	--	--	--	--	1.2	1.9	--	--	1220	7.9	7.2	90	2.0	27.5	.25	.04	.4	.97
	0430	--	--	--	--	--	--	--	--	1.3	2.1	--	--	1230	7.9	6.9	85	--	27.0	.36	.35	.6	1.0
	0730	--	--	--	--	--	--	--	--	3.5	3.5	--	--	1250	8.0	6.7	83	2.1	27.0	.16	.02	3.0	.94
	1030	--	--	--	--	--	--	--	--	4.5	4.6	--	--	1260	8.0	7.0	89	--	28.0	.16	.03	3.1	.64
	1330	24	124	23	114	7.4	333	142	--	5.3	5.3	776	404	1260	8.0	7.7	100	2.4	29.5	.14	.03	2.9	.89

Table 2.—Results of Discharge Measurements and Mean Water Discharge at Selected Sites in the San Antonio River Basin, June 16-19, 1969

SITE	STREAM AND LOCATION	RESULTS OF DISCHARGE MEASUREMENTS: RIVER MILE	DATE	TIME (24-HOUR)	DISCHARGE (cfs)	MEAN DISCHARGE (cfs) JUNE 16-19
1	San Antonio River at Farm Road 1518 near Elmendorf	203.0	June 17	0838	150.	a128
2	San Antonio River at State Highway 97 near Floresville	175.5	do	1253	142	b141
3	San Antonio River near Falls City	150.5	do	1545	152	154
4	Cibolo Creek near Falls City	131.0	June 18	1540	27.3	30
5	San Antonio River at State Highway 72 near Runge	111.0	do	0750	217	b214
6	San Antonio River at State Highway 239 near Charco	97.0	do	1019	236	b228
7	San Antonio River at Goliad	66.5	do	1245	255	260

a Discharge for station 8.18.8 at mile 205.5.
b Estimated from water-discharge profile (Figure 4).

the basis of reported plant discharges. A comparison of Figure 5 with the diurnal variations of reported discharge from the Rilling Road treatment plant (Figure 3) strongly suggests that most of the variations of the dissolved-oxygen content and BOD of the San Antonio River at site 1 near Elmendorf during the study period resulted from variations in the quantity of treated effluent released from the plant.

During the period June 17-19, the dissolved-oxygen content and BOD of the San Antonio River at site 7 at Goliad ranged from 6.7 to 8.0 mg/l and from 1.2 to 2.4 mg/l, respectively. Flow at this site averaged about 260 cfs. These data indicate that progressive dilution and bacterial stabilization of wastes downstream from site 1 near Elmendorf resulted in a decrease in the BOD and an increase in the concentration of dissolved oxygen at site 7 at Goliad. The duration of the study was too brief and the reach studied was too long to permit actual determinations of the progressive changes in BOD and dissolved-oxygen content of the water as it moved through the 136.5-mile reach. Nevertheless, profiles of the time-weighted dissolved-oxygen concentration, dissolved-oxygen deficit, and BOD for the 136.5-mile reach (Figure 6) during the period from 1200 hours on June 17 to 1400 hours on June 19 provide a generalized description of the progress of BOD exertion.

Data on Figure 6 indicate that the critical part of the reach studied (the reach in which the minimum concentration of dissolved oxygen occurred) extended from site 1 (mile 203.0) to site 2 (mile 175.5). The dissolved-oxygen content of water in this 27.5-mile reach averaged about 5.0 mg/l; the dissolved-oxygen deficit averaged about 3.0 mg/l. Although the average dissolved-oxygen content of water in this reach was constant, the average BOD decreased from 14 mg/l at site 1 to 5.1 mg/l at site 2. These data indicate that the rate of reaeration in this reach was equal to the rate of

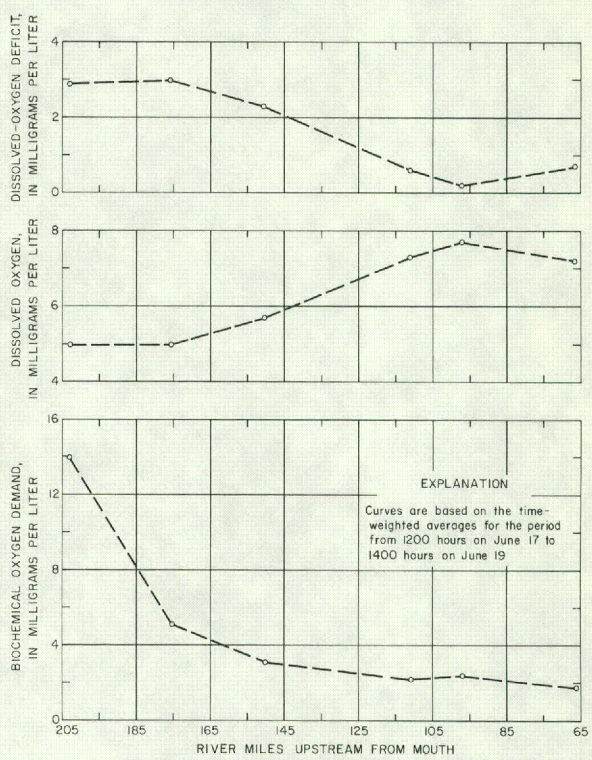


Figure 6.—Time-Weighted Averages of Biochemical Oxygen Demand, Dissolved Oxygen, and Dissolved-Oxygen Deficit for the San Antonio River

deoxygenation. Downstream from site 2 a gradual decrease in BOD usually resulted in an increase of dissolved oxygen and a decrease in the dissolved-oxygen deficit. At site 7 near Goliad, the BOD of the San Antonio River averaged 1.8 mg/l, the concentration of dissolved oxygen averaged 7.2 mg/l, and the dissolved-oxygen deficit averaged 0.7 mg/l.

At mile 131, the San Antonio River receives inflow from Cibolo Creek. The BOD of two samples collected from Cibolo Creek near Falls City (site 4) averaged about 1.6 mg/l; the dissolved-oxygen content averaged about 9.8 mg/l.

Nitrogen

Results of analyses for organic, ammonia, nitrite, and nitrate nitrogen are shown in Table 1. The diurnal variations of the total (cumulative) nitrogen content of water that passed the station San Antonio River at Farm Road 1518 near Elmendorf during the period June 16-19 are shown in Figure 7. These data for site 1 near Elmendorf show that organic nitrogen ranged from 0.54 to 1.8 mg/l, ammonia nitrogen ranged from 0.97 to 4.4 mg/l, nitrite nitrogen ranged from 0.17 to 3.1 mg/l, nitrate nitrogen ranged from 0.1 to 4.7 mg/l, and total nitrogen ranged from 2.9 to 9.9 mg/l. A comparison of these data (Figure 7) with diurnal variations of reported discharge from the Rilling Road treatment plant (Figure 3) suggests that most of the variations in the nitrogen content of the water at site 1 near Elmendorf were caused by variations in the quantity of treated effluent released by the plant.

The time-weighted concentration of total nitrogen for the San Antonio River at Farm Road 1518 near Elmendorf during the period from 1200 hours on June 17 to 1400 hours on June 19 averaged 7.6 mg/l. Dilution of waste effluent, supplemented by algal uptake of nitrogen, resulted in a decrease of total nitrogen at most downstream sites. The total nitrogen content of the San Antonio River at Goliad ranged from 1.7 to 4.2 mg/l; the time-weighted concentration of total nitrogen averaged 3.4 mg/l.

The total nitrogen content of two samples collected from Cibolo Creek near Falls City averaged 1.7 mg/l.

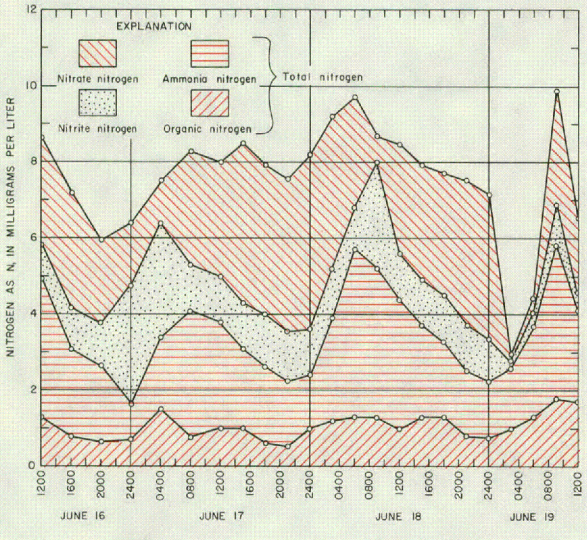


Figure 7.—Diurnal Variations of Organic, Ammonia, Nitrite, Nitrate, and Total Nitrogen, San Antonio River at Farm Road 1518 near Elmendorf

Phosphate

Results of analyses for orthophosphate and total phosphate are shown in Table 1. The diurnal variations of total phosphate for the San Antonio River at Farm Road 1518 near Elmendorf are shown in Figure 8. These data for site 1 near Elmendorf show that the total phosphate ranged from 2.1 to 19 mg/l. Correlation of data in Figure 8 with the reported discharge of treated sewage effluent from the Rilling Road treatment plant (Figure 3) suggests that most of the variations of the total phosphate content of the San Antonio River at site 1 near Elmendorf was caused by variations in the quantity of treated effluent released from the plant.

During the period from 1200 hours on June 17 to 1400 hours on June 19, the time-weighted concentration of total phosphate of the San Antonio River at Farm Road 1518 near Elmendorf averaged 9.7 mg/l. Dilution of waste effluent, probable algal uptake of phosphate, and possibly some absorption by sediment resulted in a decrease of the concentration of phosphate at downstream sites. The total phosphate content of the San Antonio River at Goliad ranged from 1.6 to 5.3 mg/l; the time-weighted concentration averaged 2.5 mg/l.

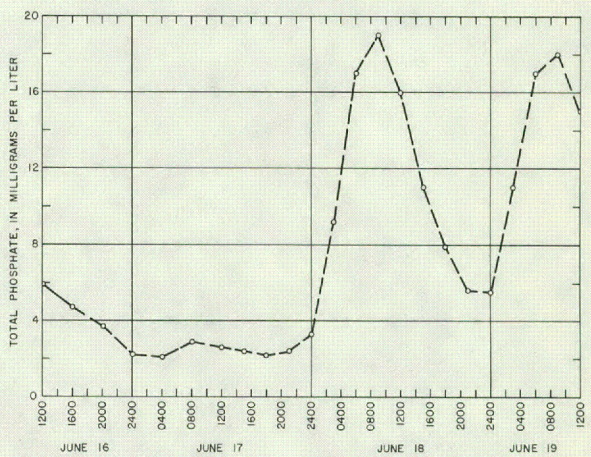


Figure 8.—Diurnal Variations of Total Phosphate, San Antonio River at Farm Road 1518 near Elmendorf

The total phosphate content of two samples collected from Cibolo Creek near Falls City averaged 0.16 mg/l.

SUMMARY OF CONCLUSIONS

During the period June 16-19, mean discharge of the San Antonio River ranged from 128 cfs at site 1 near Elmendorf (mile 203.0) to 260 cfs at site 7 at Goliad (mile 66.5). Most of the flow at the site near Elmendorf was treated sewage effluent on the basis of reported discharges. The quantity of treated effluent released into the river about 18 miles upstream from the site near Elmendorf ranged from 46 to 138 cfs and averaged about 100 cfs. Variations in the quantity of releases caused variations in the quality of water in the San Antonio River. The ranges of selected water-quality parameters or constituents at site 1 near Elmendorf were as follows: BOD, 9.0 to 20 mg/l; dissolved oxygen, 4.4 to 5.6 mg/l; total nitrogen, 2.9 to 9.9 mg/l ; and total phosphate, 2.1 to 19 mg/l .

During the period from 1200 hours on June 17 to 1400 hours on June 19, the time-weighted averages of selected water-quality parameters or constituents for site 1 near Elmendorf were as follows: BOD, 14 mg/l; total nitrogen, 7.6 mg/l; and total phosphate, 9.7 mg/l. The critical part of the reach studied extended from site 1 (mile 203.0) to site 2 (mile 175.5). The dissolved-oxygen content of water in this 27.5-mile reach averaged about 5.0 mg/l; the dissolved-oxygen deficit averaged about 3.0 mg/l. Downstream from site 2, dilution of waste effluent, supplemented by bacterial stabilization of organic matter and probable algal uptake of nitrogen and phosphorus, resulted in an increase in the dissolved oxygen and decreases in the dissolved-oxygen deficit, BOD, and concentrations of total nitrogen and total phosphate. The time-weighted averages of these water-quality parameters or constituents for the San Antonio River at site 7 at Goliad were as follows: BOD, 1.8 mg/l; dissolved oxygen, 7.2 mg/l; dissolved-oxygen deficit, 0.7 mg/l; total nitrogen, 3.4 mg/l; and total phosphate, 2.5 mg/l.

REFERENCE CITED

Dupuy, A. J., Manigold, D. B., and Schulze, J. A., 1970, Biochemical oxygen demand, dissolved oxygen, selected nutrients, and pesticide records of Texas surface waters, 1968: Texas Water Devel. Board Rept. 108, 38 p.